



RCA INSTITUTES

INC.
formerly
MARCONI INSTITUTE
Founded 1909



Technical Lesson 59

RADIO AVIATION EQUIPMENT

Air transportation, a dream of many years, has now become a practical reality, and it is a common sight to see airplanes carrying passengers, mail and express. As to be expected, radio has become an important factor in connection with flying and is used to serve air navigation just as it does marine navigation. It is agreed that a radio wave or beam is the only beam capable of penetrating fogs or mists to any great distance and, obviously, radio provides the only means of contact between an airplane in flight and the ground when atmospheric conditions make visibility naturally low. Hence, radio by its fundamental nature aids air navigation in the following important ways: In furnishing direct communication between airplanes in flight and the ground, and directional indications to pilots for guiding their airplanes along established airways.

The value of radio to aviation was fully appreciated by the Airways Division of the Department of Commerce and to increase the reliability and safety of air travel it planned a system of radiobeacon transmitters at important airports throughout the country. These transmitters send out a signal which produces narrow beams that coincide with the lighted civil airways already established to guide aircraft along air routes over which most of the flying takes place. Beside the directional radiobeacon signals, service is rendered by broadcasting information in the form of weather reports and other news of importance to fliers. An air route is called an "airway" and a radiobeacon station is referred to as a "radio range."

The directive properties of a cross-loop antenna system are used to produce the radio beams in the desired directions along the established civil airways. Since the "aural" type of directive radiobeacon is used then any pilot, providing he is flying along an airway and has his receiver properly tuned, can listen to either the beacon signal or the broadcast. The beacon signal consists of International Morse code characters, letters A and N, which are heard individually or blended together into a long dash, or letter T, depending upon whether the plane is on or off the course. Should the airplane deviate from the course, the signals will tell the pilot his exact position and permit him to locate it again and thus direct him to the airport and into the landing field at which the radiobeacon station is located.

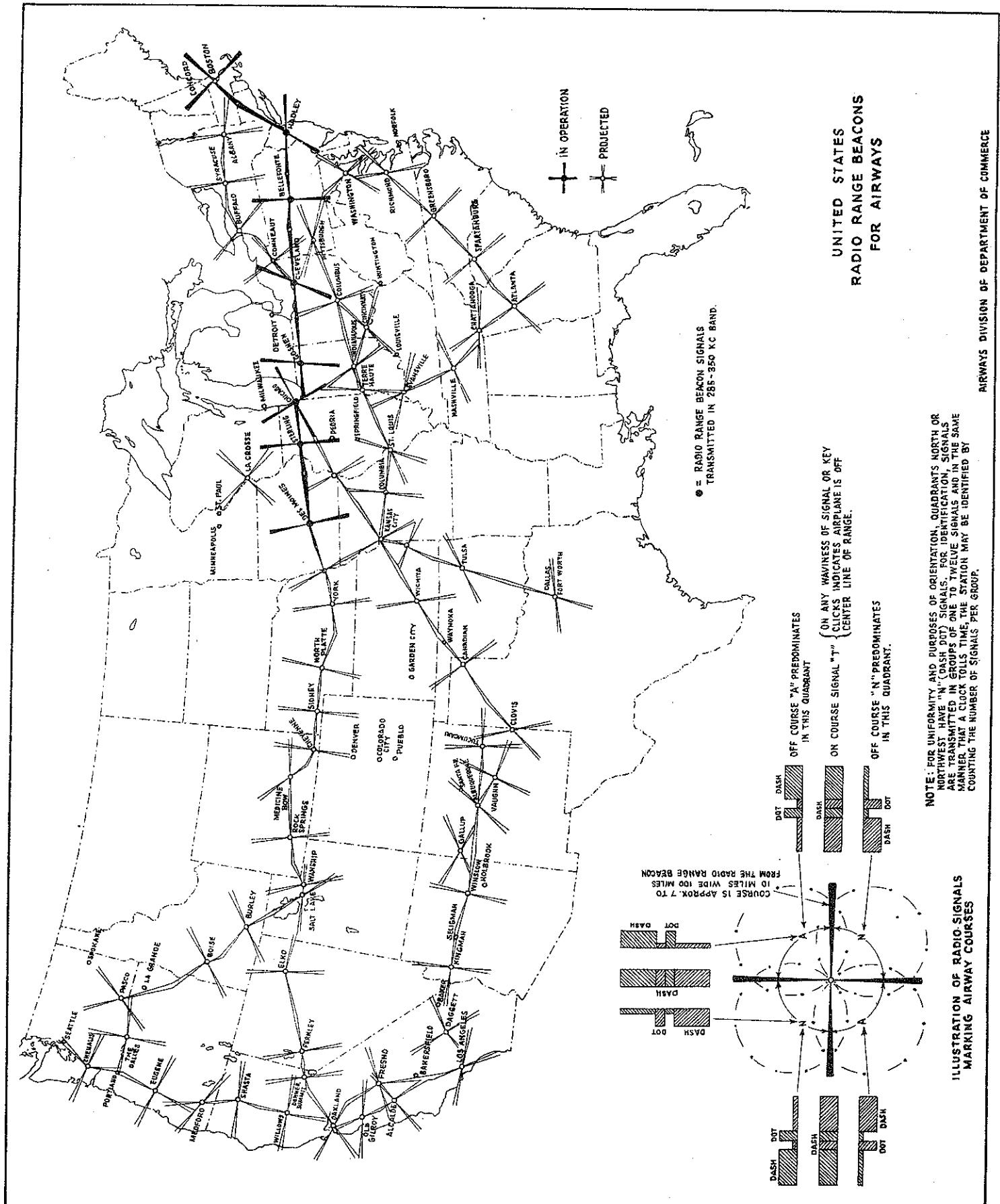
Since the majority of airplanes are used for transportation they must operate on fixed schedules day-in and day-out and during all kinds of weather. As an aid in helping airmen maintain a schedule a radio wave sent out by a radiobeacon station serves their needs especially at times when the powerful searchlights which beam along the airways cannot be seen due to unfavorable weather conditions. At the present stage of development radio telephony is most practicable for one-man planes such as those that fly the mails, but in the large passenger-type planes which carry an operator provision is made to use CW telegraphy where long distance must be covered and telephony is used for stand-by.

To judge how important radio is to aviation we have only to realize that radio is the only means of making contact with airplanes in flight. We will now mention many important services which radio can provide for air navigation. With only a receiving set aboard the aircraft the service between ground stations and aircraft would include the reception of the radio range beacon signals which mark out the airways, weather reports and forecast, and other information such as the proximity of other airplanes and so on. With two-way communication provided by a radio transmitter and receiver on the plane, we can summarize the services as follows: (a) a pilot can remain in direct constant communication with his home airport, (b) he is able to ask for information when shut in by fog, snow, rain, or storms and during night flying, (c) he can summon aid in times of distress as in the case of a forced landing and, (d) he can guide his airplane in flight along a definite route through the air by means of the directive signals sent out by a radio range like a motorist follows a routed highway.



Figure 1

RADIO RANGE OR RADIOBEACON STATION. The interior of the Airways Radio Station of the Department of Commerce located at St. Louis, Mo., is shown in Figure 1. Stations similar to this one are located at points approximately 200 miles apart along established airways in the United States. This photograph shows the essential equipment in such a station which consists of a combined 2 kw telegraph and telephone intermediate-frequency transmitter for sending out the signal for directive purposes and radio telephone for broadcasting weather service and other information to airplanes for their safety in flight. In addition, a short-wave transmitter, Department of Commerce built, shown at the



AIRWAYS DIVISION OF DEPARTMENT OF COMMERCE

Figure 2

extreme left in the photograph is used for point-to-point communication. Then there is the receiving equipment necessary to carry on this service which consists of a short-wave and long-wave receiver; the long-wave receiver on the operator's table being a model IP-501. Teletype machines are also provided which print on a paper tape all information important to flyers, and this appears at each station in the circuit and landline telephone and telegraph are also employed in collecting and distributing this information between stations.

The procedure now in use is to transmit the radiobeacon signals in conjunction with the radio broadcasts on the same frequency. The signals are sent out continuously except during four three-minute periods at the quarter hours at which time the radio telephone broadcasts are made. The beacon is cut off every 15 minutes and identified by station announcement, followed by correct time and weather reports and other announcements and then, on completion of the broadcast, the beacon is again placed in operation. Frequency channels have been set up for this service by the Federal Radio Commission, a particular channel being used along a given air route regardless of the number of transport companies flying that route. This system may be interrupted at any time to send emergency messages to pilots in flight.

It is to be understood that all airport stations owned by the commercial airport companies operate on a calling and working frequency of 278 kilocycles set up by the Federal Radio Commission. Since airport transmitters are used to give orders to pilots by radiotelephone as to landing procedure when weather conditions make it necessary, their range must not exceed five miles so as to prevent interference between neighboring airports.

RADIO RANGE BEACON SYSTEM FOR AIRWAYS. The map in Figure 2 issued by the Airways Division of the Department of Commerce shows the general plan of the civil airways system and locations of the radio range beacon transmitters which are either in operation or are proposed. The paths of the four routes pointed out by the signals of each transmitter are indicated; these indicated paths are actually radio waves in space and, although they cannot be seen, nevertheless they are referred to as beams. Each beam shoots out for a distance of about two hundred miles in a certain direction but covers only a small area in width. When these radio waves or signal beams are picked up by the antenna of an airplane flying a given course and are reproduced by the radio receiver they indicate to the pilot his exact location, that is, whether or not the plane is on the airway marked out by the beacon.

From the map we can see that the important routes or airways across the country and along the coasts do not always lie in a straight line. Since four beams are radiated from the antenna of a radio range and they are normally equally spaced and, therefore, 90 degrees apart, it is necessary in many cases, as the map indicates, to shift the angle between beams in order they they will project out in the proper direction to coincide with the airways. It is of interest to know that in the case of the New York — Cleveland Airway served by the radio-beacon at Bellefonte, it required shifting the angle between the beams from 180 degrees to 166 degrees because Hadley Field, New Brunswick, N. J. is a few miles north of a location which would make this airway lie in a straight line.

Smaller radio beacons called "marker beacons" with a transmitting range of about five miles are located at the intersection of adjacent courses and are arranged to send out a special characteristic signal modulated at about 1000 cycles alternately on the different frequencies used by the intersecting courses. The

marker beacon signal informs the pilot that he is leaving one course and entering the next and, therefore, should retune his receiver to the frequency on which the adjacent radio range is operating. We suggest that you carefully examine the sketch in the lower left of the map because it explains in a simple way the principle upon which the aural type of directive beacon operates.

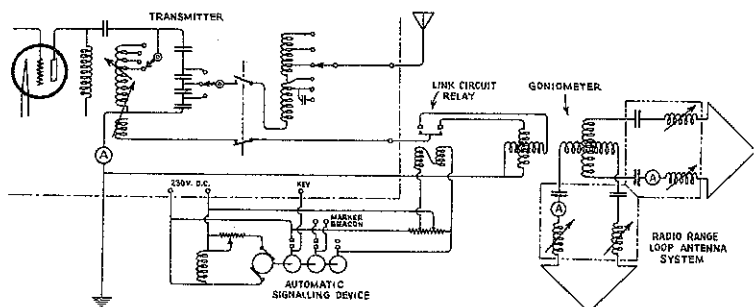


Figure 3

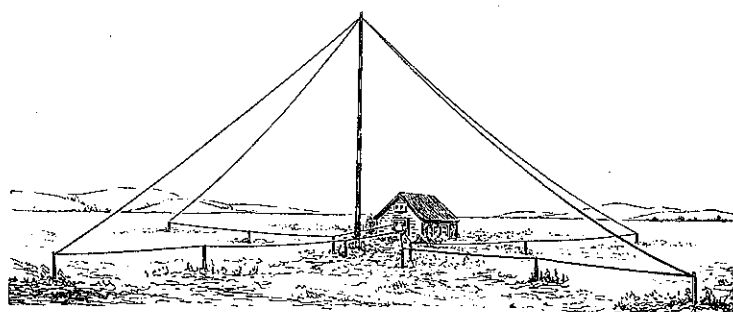


Figure 4

EXPLANATION OF A RADIOBEACON STATION. A radiobeacon station is usually located as near as practicable to a landing field. The essential circuits for supplying the required signals and the antenna system which produces the beams because of its directional properties are shown in Figure 3. The antenna system consists of two loops placed at right angles to each other and supported on poles as illustrated in Figure 4. In the small building at the foot of the center pole are the radio transmitter, automatic signalling device, link circuit relay, goniometer, and the two loop antenna units each of which is supplied with antenna ammeters, and other apparatus required in the operation of the radio range. There are four lead-in conductors which pass through glass insulators in the side of the building and connect the antenna loops to the goniometer and antenna units just mentioned.

The link circuit relay and automatic signalling device are mounted in a single unit between the transmitter and goniometer. This unit contains the rheostat for controlling the speed of operation of the signalling device. The goniometer serves to couple the output of the transmitter, or characteristic signal formed by the dots and dashes into the loop antenna system but its main function is to direct the four radio beams in certain directions from the antenna and permit the desired degree of sharpness of the beams to be obtained.

The picture in Figure 4 suggests the size of the two antenna loops which are crossed at an angle of 90 degrees to each other. The approximate physical dimensions of each loop would be represented by a triangle having an altitude of 70 ft. with a bottom line or base 300 ft. in length, the base being elevated about 10 ft. above the ground. The frequency band covered by radio range equipment is from 285 to 315 kilocycles, or 1050 to 950 meters.

First consider the signalling device. It consists of a motor which drives a set of especially shaped discs or cams which "make" and "break" the circuit as they rotate and, hence, the device transmits the Morse code characters A and N as you would do if you were sending these letters alternately on two Morse telegraph hand keys. (Letter A is $\cdot -$ and N is $- \cdot$) To be more exact the cams are so timed to send the A and N in such a way that no portions of the two characters are transmitted simultaneously, and also the two letters are supplied alternately to the two loops by the relay. Thus, the system works as

follows: The dash in N is sent first on one loop, the dot in A is sent next on the other loop, the dot in N is then sent on the first loop, and lastly the dash in A is sent on the second loop. So, if you heard these signals in your earphones and all of the dots and dashes followed one another in succession and without intervals and all were of equal strength, then, the effect would be to hear one long dash of constant signal strength. When the characters combine into a long dash it is referred to as blending or "interlocking" of the A and N signals. Hence, the reception of a series of dashes, which would sound like dah-dah-dah- and so on, would tell a flier he is travelling in a direct line with the beam and is therefore on the course. Now, if an airplane were flying in any area between the line of the beams one of the individual letters would be heard strongest depending upon which side the airplane was off the course. Also, any waviness of the signal or key clicks heard indicates the airplane is off the center line. The individual letters A and N which comprise the signal are sent at a rate which would correspond to about 22 words per minute, counting 5 letters to a word and in groups of from 1 to 12 signals in the manner that a clock tolls time, so that a beacon station can be identified by the number of signals per group.

VISUAL TYPE RADIOBEACON INDICATOR. A type of radio range that will operate a visual indicator to be mounted directly in front of a pilot on the instrument board is being perfected by engineers of the Airways Division. Figure 5 shows a visual indicator. It is electrically connected to the output of the aircraft beacon receiver in place of the headphones, and consists of two electromagnets and two strips of metal called "reeds." The tips of the reeds are painted white and are made of an alloy having superior magnetic properties, or a high permeability and are mounted alongside of each other. With the visual system,

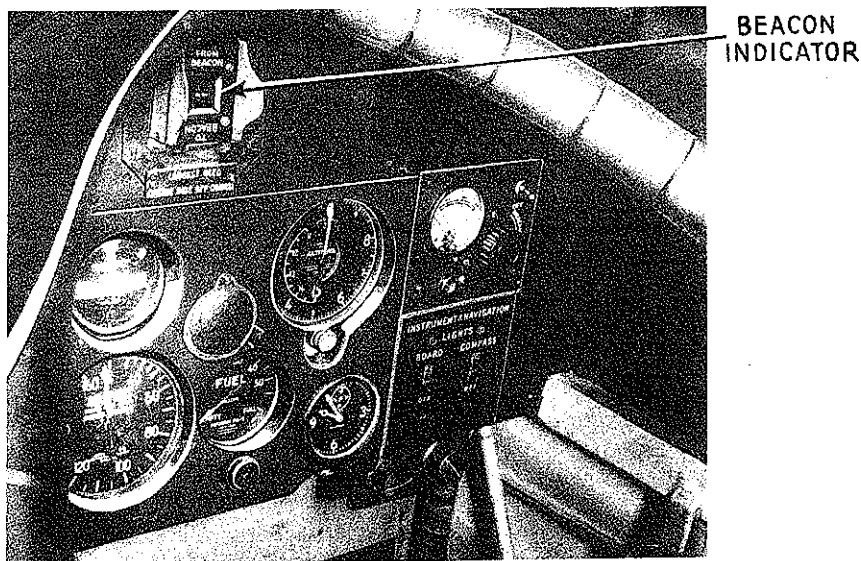


Figure 5

when beacon signals are received, the two reeds vibrate vertically since they are mechanically tuned to two modulation frequencies transmitted simultaneously by the beacon, that is, to frequencies of 65 and 86.7 cycles per second. When the two frequencies pass through the radio receiver with equal strength the reeds respond by vibrating with equal amplitudes and the effect is that the pilot sees two broad white lines which appear equal in size. Hence, so long as the areas of the white lines are equal in size a pilot knows his airplane is

on the course. However, if the airplane deviates from the course, one reed vibrates with greater amplitude than the other and this appears to the eye as though one line has been made larger or smaller than the other. When the airplane flies to the left of the course the left reed vibrates strongest and, consequently, the size of the left white line is increased, and the right reed is reduced, and the same holds true if conditions are reversed. The indicator must be turned by the pilot to make either the words "TO BEACON" or "FROM BEACON" read rightside up depending upon whether the airplane is flying toward or away from a given beacon. This is done so that the longest reed will always indicate the side off course and inform the pilot to steer in the direction toward the shorter reed.

PRINCIPLE OF "BENDING" OR "SHIFTING" RADIOBEACON BEAMS. It is well-known that a simple loop has directive properties and, therefore, the signals it sends out will be strong from one side and weak from another. This unequal distribution of radio energy in the field set up around an active loop antenna system would be detected if you travelled around making tests with a portable receiving set. To illustrate this difference in signal intensity we use circles such as those shown in the drawings below. A simple loop emits a wave of maximum intensity in a direction in line with its own plane and minimum at right angles thereto. Figure 6A explains this as follows: Circles C1 and C2 show that the energy radiated by the "A" loop is maximum in an up and down direction looking at this page and minimum in a direction across the page. This same relationship exists for the "N" loop, its directive properties being shown by circles C3 and C4. These circles and heart-shaped curves called cardioids illustrating relative intensity of radio waves in space are called "field patterns."

ON THESE FOUR COURSES THE LONG DASH IS FORMED BY THE UNITING OF THE TWO LETTERS OF EQUAL STRENGTH (A & N SIGNALS OF EQUAL STRENGTH)

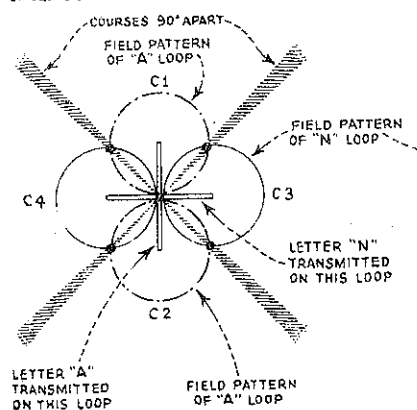


Figure 6A

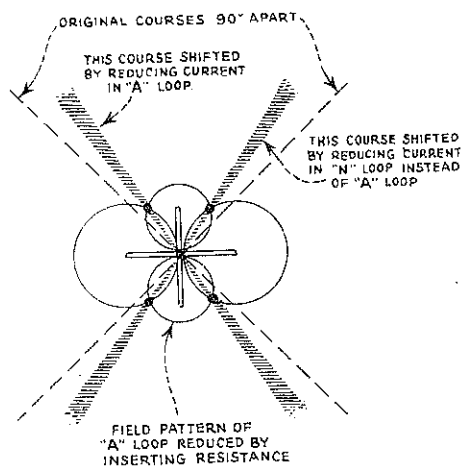


Figure 6B

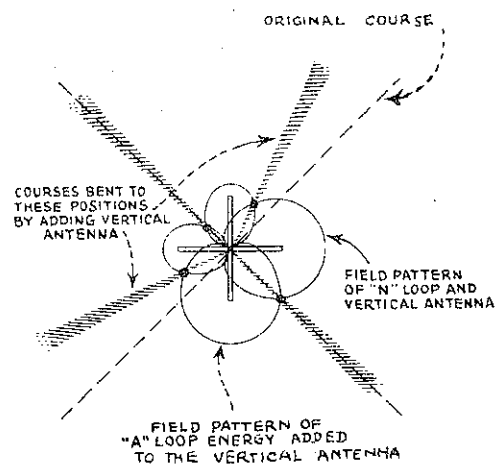


Figure 6C

The effect of normal radiation of the crossed loops of a radio range is pictured in Figure 6A, and here we see four courses provided at 90 degrees apart since the r-f current in each loop is the same and, hence, the radiation is the same. Remember that in the aural system a course or radio beam occurs in a line along which energy in the "A" signal and "N" signal are equal, these locations being marked by heavy dots. Engineers of the Airways Division have worked out two methods for bending the beams the desired amount to line them up with established airways. One method for obtaining the desired effect is accomplished by the use of a suitable resistance inserted in either loop to

increase or decrease the r-f current in the loop; this produces courses as shown in Figure 6B. Another method consists of supplying the circular radiation of a vertical wire antenna in addition to the radiation of the loops. A vertical antenna has no directional properties; it radiates equally well in all directions and, hence, its energy acts on the loop energies to produce an effect as shown in Figure 6C. Comparing the three drawings which are largely self-explanatory note how the field patterns differ in every case and that wherever the A and N signals are equal a course is produced. Since the beams are about 3 degrees wide and travel in a line outward from the beacon for a couple of hundred miles, then the closer an airplane is to the beacon the narrower and sharper the beam becomes.

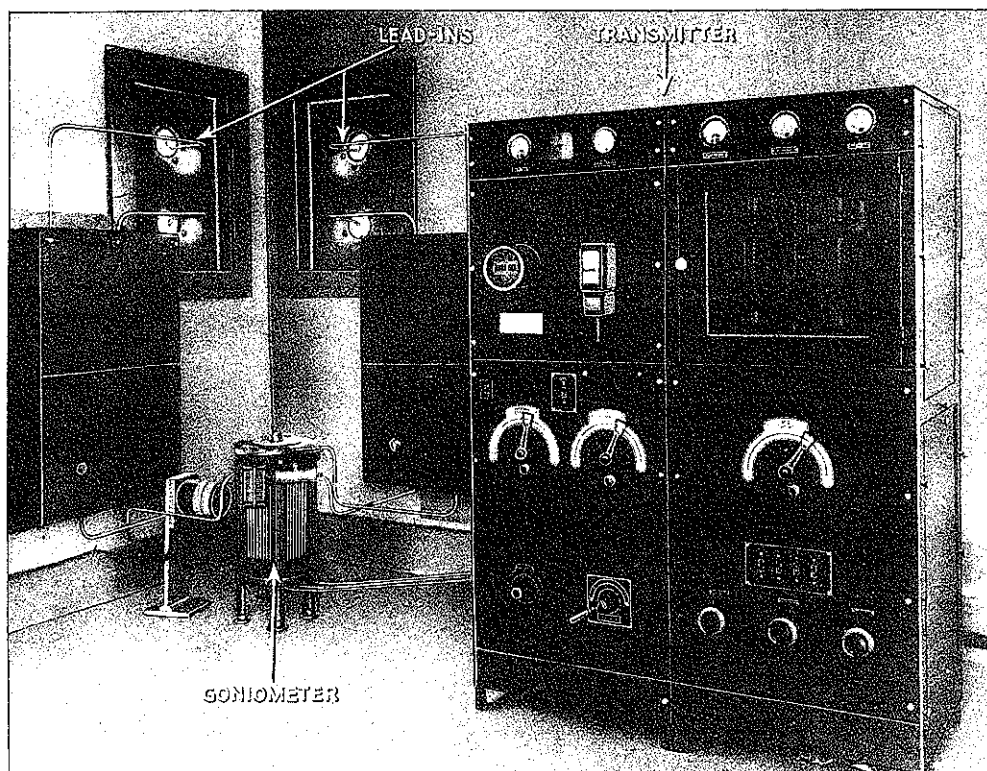


Figure 7

2 KW. RADIO TRANSMITTER. The transmitter illustrated in Figure 7 is used for radio range service at the Airways Radio Station at Hadley Field, just outside of New Brunswick, N. J. A transmitter of this kind may also be used at airports for point-to-point communication or for communication from airports to aircraft. Of special interest are the goniometer and the two loop tuning units shown mounted on the wall which are built into metal frames and completely shielded. An antenna ammeter is provided in each tuning unit for use in tuning the antenna loop with which it is used. Observe how the four lead-in conductors which connect to the crossed-loop antenna system pass out-of-doors through glass insulators installed in the wall. For radiobeacon work this range equipment will ordinarily use only tone modulated telegraphy, this being accomplished by modulating the transmitter through the regular audio system included in the modulator unit, using an audio-frequency oscillator for obtaining the desired frequency. When radio telephone transmission is used for broadcasting weather service the high-frequency generated by the transmitter is modulated by the voice frequencies passing to it from the microphone and the modulator circuits.

AIRPORT RADIO TELEPHONE AND TELEGRAPH TRANSMITTER. Inasmuch as the various air transport companies, or airway systems as they are sometimes called, are engaged in flying the mails and carrying passengers and cargo they necessarily have certain obligations to meet in safeguarding the lives and property of those who use this modern method of transportation. Also, the service rendered must be reliable to retain the support of the flying public and this requires that established schedules be maintained day-in and day-out and often under the most unfavorable weather conditions. It is easy to appreciate, therefore, that an airways system can facilitate the handling of traffic which includes among other things, the arrival and departure of its planes, by employing radio for communication purposes at airports or terminals under its control. A typical radio transmitter for use at airports is described in the following paragraphs. The transmitter, known as model ET-3666 and pictured in Figure 8, consists of two main units; the unit at the left being the radio-frequency portion of the set, and the one at the right the modulator.

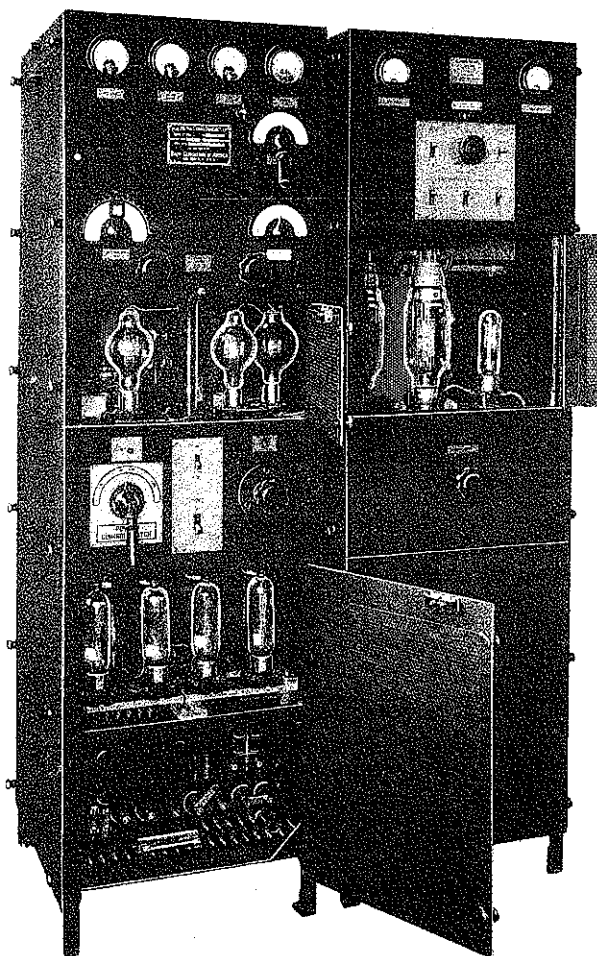


Figure 8

The equipment for a transmitter of this type includes other apparatus not shown in the photograph such as a telegraph key, start-stop switch, send-receive switch, microphone, storage battery and so on. When connected to a suitable antenna system the output of the power amplifier will deliver 200 to 350 watts of continuous wave (CW) radio-frequency energy. It is to be noted that such a transmitter provides continuous wave telegraphic transmission only,

and it is by the addition of the modulator unit that telephone transmission is also made available. This airport transmitter operates in the low wavelength or high-frequency band. Its radio-frequency circuits cover a continuous frequency range of from 2000 to 6000 kilocycles, which in terms of wavelength represents a band from 150 to 50 meters. When special coils are used in the transmitter, the r-f circuits will cover a still lower waveband, or one extending from 5900 to 17200 kilocycles, which is 54 to 17.5 meters.

By employing the master oscillator-power amplifier type of radio-frequency circuit the signals radiated by the antenna are kept at practically a constant frequency, that is to say, the signals will not waver appreciably above or below the assigned frequency. This condition is to be desired in any transmitter because the operator at the receiving station can copy a code message or listen to a spoken communication depending upon which method of transmission is used at the time, without the annoyance of occasionally readjusting his tuning dials. Furthermore, frequency stability in a transmitter tends to lessen or prevent interference between stations in congested wavebands, and especially those which are assigned to aviation. The allowable difference between the frequency assigned and that actually transmitted is governed by the waveband and the class of radio service — broadcast, marine, aviation, and so on.

The special features of the control circuits of this airport set are given in the following paragraphs. The transmitter is provided with a local "start-stop" switch which is mounted on the front of the transmitter panel and, in addition, an external "stop-start" switch from a remote point can be connected in parallel with the switch on the panel to enable the operator to control the set from one or the other of these two switches. When the "start-stop" switch is placed in the "start" position voltage is applied to the filaments of the radio-frequency and rectifier tubes and also to the delay action relay. The relay contacts control the d-c supplied to the plates of the tubes. It is necessary to have a delayed action relay to prevent the load of the plate circuits from being thrown on the rectifier tubes until a certain time has elapsed after applying filament voltage to the tubes. A time interval of about 30 seconds in the operation of the relay between the closing of the filament circuits and the plate circuits is sufficient to provide proper protection for the rectifiers.

The transmitter includes a "send-receive" relay controlled by a "send-receive" switch for transferring the antenna and ground connections from the transmitter circuit to a receiver, when a receiver is located close to the transmitter. This send-receive switch interlocks the coil of the main plate contactor in such a way that plate voltage is not supplied to the rectifier tubes excepting when the send-receive relay is in the "send" position. The control circuits also include a main power switch which serves to remove all power from the various transmitter circuits with the exception of the 6 volt storage battery circuit. Keying the transmitter for telegraphic operation is accomplished in the usual way by means of a telegraph key generally placed on the operator's table. A test key located above the power control switch on the transmitter panel has its contacts in parallel with the contacts of the telegraph key. The test key is used for convenient operation while adjusting the transmitter at any desired frequency within its band.

The power supply from an electrical transmission line required for operating this equipment is 220 volts a-c, 3 phase, 60 cycles. This includes all power for operating the transmitter and rectifier circuits, with the exception of a small amount of energy supplied by a 6 volt storage battery for keying relay and microphone.

In the photograph in Figure 8, the screen doors of both the transmitter and modulator units are open which permits a clear view to be had of the vacuum tubes used in this set. Note that the r-f circuits of the transmitter unit utilize the latest four-element UX-860 screen-grid tubes; there is one UX-860 tube used as a master oscillator and two UX-860's as power amplifiers. In the power circuits six UV-872 tubes are used as rectifiers. A plate transformer which connects to the 220 volt a-c line supplies power to the rectifiers. The tubes required to accomplish telephone operation are in the modulator unit at the right and they consist of one UX-860 used for a speech amplifier and two UX-849's for modulators.

Note that the indicating instruments located at the top of the transmitter panel consist of a plate ammeter, antenna ammeter, plate voltmeter, and filament voltmeter. Directly below this set of instruments, and to the right of the panel, is located the control for the antenna tuning capacitor, and below this is the control for the power amplifier tuning capacitor and directly to the left of the latter is the control for the master oscillator tuning capacitor. Observe that below the tuning controls just mentioned are the master oscillator and power amplifier tubes. On the control panel located below these tubes are the power switch, the filament rheostat control, the test key, the internal stop-start switch, and the main line switch. In the bottom compartments below the control panel are seen the rectifier tubes and the terminal board, the various relays and contactors.

At the top of the modulator panel are the plate ammeter and filament voltmeter while below these are three tumbler switches which make it possible to read the individual or collective plate currents of the audio tubes. It should be mentioned that whenever a remote station is operated in conjunction with a main airport station and they are at a considerable distance from each other it will require a line amplifier to boost up the strength of the audio currents in the microphone circuit to a suitable value for operating the audio amplifier in the modulator unit.

100 WATT AIRCRAFT RADIO TRANSMITTER. The principal units of a typical aircraft transmitter installation consist essentially of a transmitter, a receiver which is described in the latter part of our lesson, a filter unit, a control box, an antenna ammeter, an antenna reel with 300 ft. of wire, headphones and microphones. Also, an air propeller and double-current generator called a wind-driven generator, or a dynamotor and storage battery are required to supply the necessary operating voltages to the set. A receiver would get its power supply from the same source as the transmitter. In the illustration in Figure we see the separate units of an airplane transmitter, the different components being clearly marked for identification. These units are distributed about the fuselage of the plane in any convenient location and only the control unit and jack box and antenna ammeter need be within reach of the pilot or operator. The control unit in the photograph is for a model ET-3653-A radio aircraft transmitter to provide two-way communication with stations on the ground.

The explanations following will give you a good idea of the special features concerning a typical light weight and compact aircraft transmitter. By careful designing a complete unit for combined telephone and telegraph transmission has been produced which weighs only about 28 lbs. In Figures 10 and 11 you will see the transmitter unit with covers removed. These interior views show the present form of one type of modern aircraft transmitter. Note in the photograph on the left how all of the four tubes are mounted on one side of a

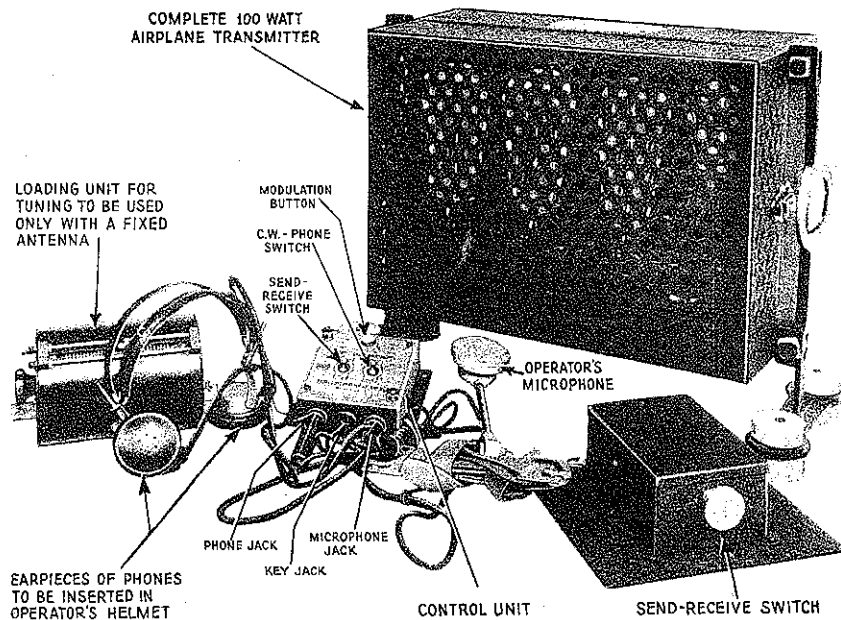


Figure 9

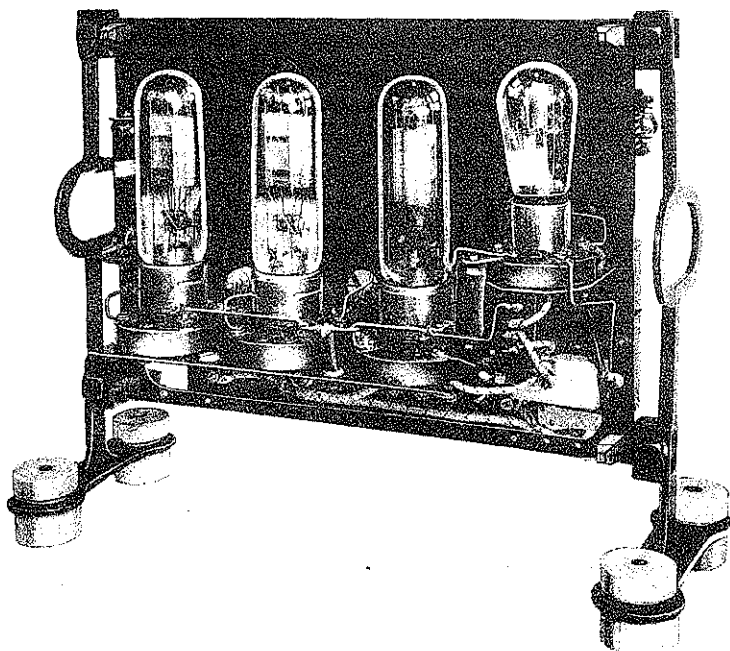


Figure 10

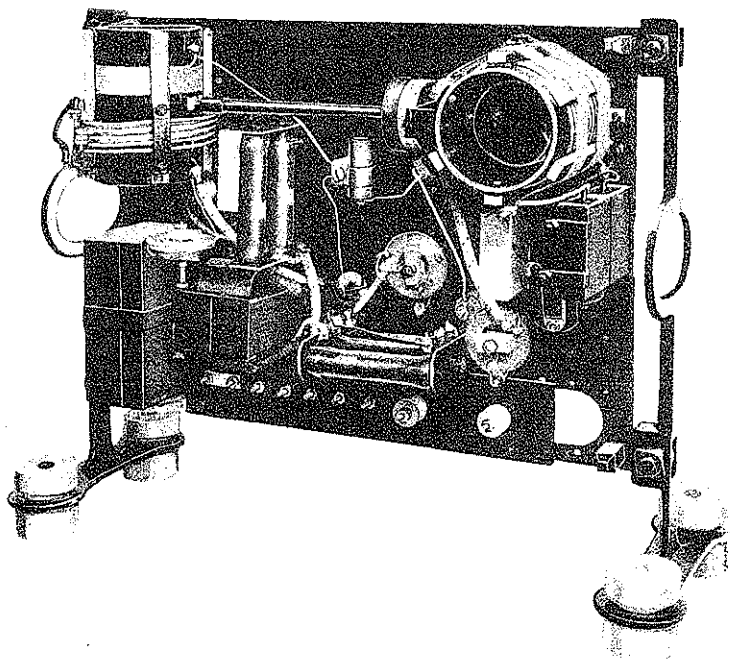


Figure 11

vertical partition or panel which runs lengthwise of the set. In the photograph on the right showing the rear view, note how the different parts which are required in the generation of high-frequency current are supported. The parts include the antenna coupling transformer, neutralizing condenser, several fixed condensers, the master oscillator tuning inductance, resistors and so on. This form of construction makes the parts easily accessible for inspection, testing and servicing which is important in aircraft radio maintenance. A special cable form with disconnecter blocks permits the transmitter to be quickly disconnected from the power source.

The circuits of the transmitter function in a manner similar to other transmitters in that they convert the electric power output from a generator into a form which when connected to an antenna will produce the radiation of radio waves. Now refer to the schematic diagram of this transmitter in Figure 12. The master oscillator-power amplifier type of circuit with a Hartley oscillator is shown in the diagram. In its circuits are generated the carrier frequency that is delivered to the power amplifier whose output in turn feeds the antenna system by means of an antenna transformer. Antenna tuning is accomplished by changing the length of the trailing wire, after the desired frequency has been set on the master oscillator. In order to make it possible for the operator to

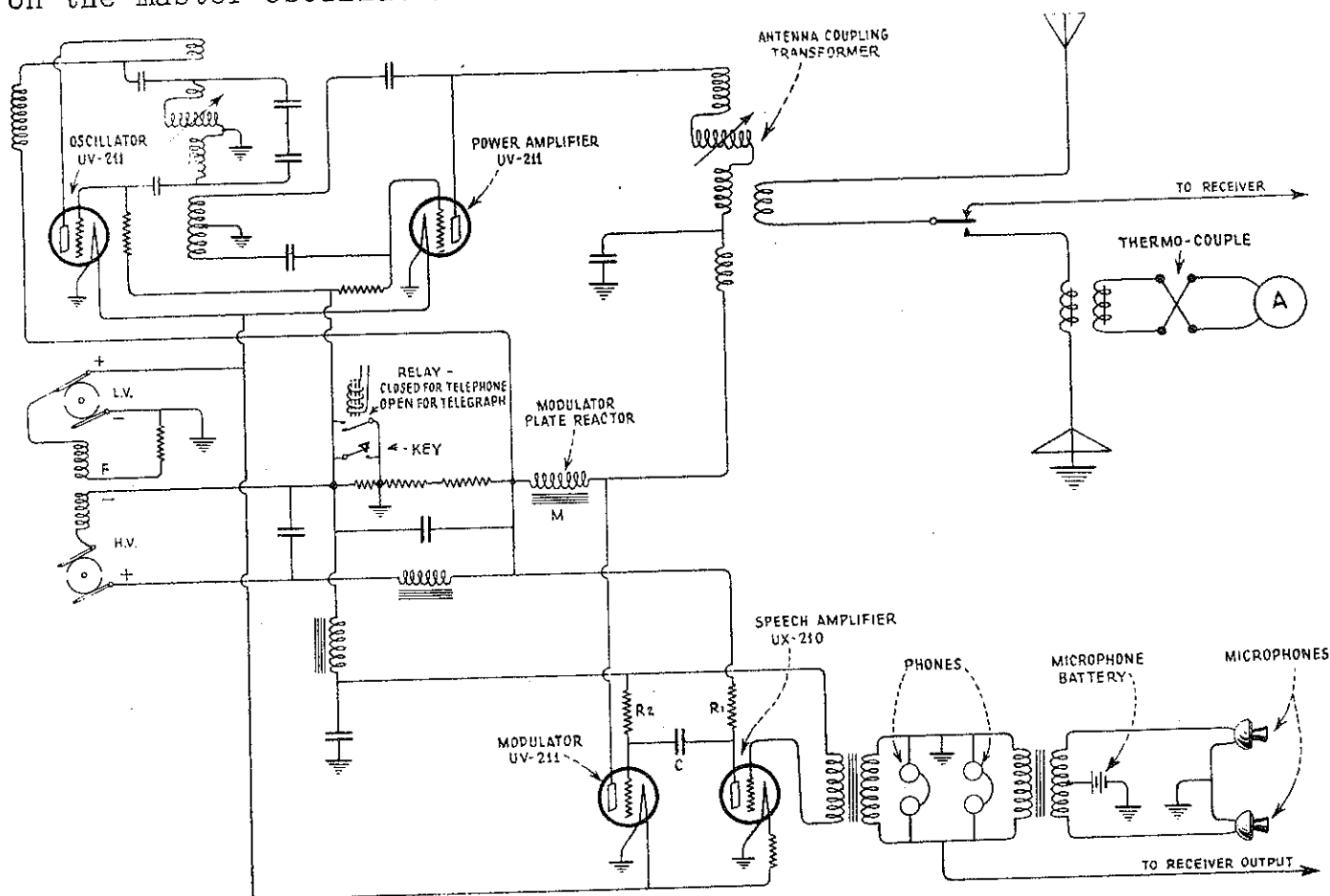


Figure 12

adjust the antenna tuning satisfactorily, a small meter for indicating resonance, called an antenna ammeter, is coupled to the antenna circuit through a transformer. The meter is mounted conveniently within sight of the pilot or operator. It is provided with a 0-5 ampere scale and is operated from a thermo-couple so that no radio-frequency current is carried by the leads connecting the meter to the transmitter. The meter tells at a glance when the antenna is properly resonated and normal antenna output is obtained.

There are two methods of signalling provided by this transmitter — radio telephone and continuous wave (CW) telegraph. Telephone communication is effected by means of an anti-noise microphone, microphone transformer, and modulation reactor, using the Heising or constant current system of plate modulation.

In brief the reactor, marked M on the schematic diagram, keeps the direct current supplied to the plates of the modulator and power amplifier at a substantially steady value, and the audio current in the microphone circuit causes variations in the plate current passing through the tube by varying its grid voltage through the resistance coupling unit, marked R₁, R₂, and C. In addition to the microphone and output windings, the microphone transformer has a side-tone winding which is connected across the headphones of the two operators and across the receiver output. The purpose of this is to allow the headphones to be used for interphone communication between a pilot and co-pilot, or operator at all times on board the aircraft, and also for listening-in on what is being transmitted over the radiophone and for the reception of incoming radio signals without the necessity of switching any headphone connections.

Telegraph communication is obtained by means of a manually operated key, the tubes being biased to cut off when the key is up, and normal bias and consequently normal output being obtained with the key depressed. There is no radiation from the transmitter when the key is up, since plate current is zero.

For aviation purposes a special air-tight telegraph key is used which eliminates possibility of sparking contacts igniting fumes, and an anti-noise microphone similar to the type shown in Figure 9 is so constructed that motor and propeller noises have almost no effect on it, but when the operator speaks directly into it the diaphragm will be actuated and his voice will be transmitted. The control box unit shown connected to the aircraft transmitter contains switches for changing from "send" to "receive" and from "CW telegraphy" to "telephony," and the necessary jacks for inserting the plugs attached to the key, microphone, and headphones.

In regard to the waveband covered by this 100 watt transmitter it should be mentioned that transmission can be effected on either of two frequency ranges, namely; 2250 to 2750 kc (109 to 133 meters) and 316 to 600 kc (600 to 950 meters). With the radio-frequency circuits adjusted for the latter band either a trailing antenna or fixed antenna may be used.

POWER IS OBTAINED FROM A WIND-DRIVEN GENERATOR OR A DYNAMOTOR. In connection with aircraft transmitters the voltage supply for the various circuits offers special problems. At the present stage of development of aircraft radio the transmitters and receivers used in the larger type planes normally obtain their power supply from a wind-driven generator or a dynamotor which is fed from the plane's storage battery. The battery usually is a 12 volt landing light battery and is kept in a charged condition by a wind-driven generator. The dynamotor method makes it possible to transmit when a plane is not in flight which would be especially advantageous to a pilot in case of a forced landing. A wind-driven generator is mounted outside the plane, usually on a strut, and is driven by a single blade propeller which is self adjusting so that it maintains the speed of the generator at about 4000 r.p.m. This regulating feature is due to the centrifugal force developed with increased speed which acts on weights so placed as to cause the blade to turn through an angle of pitch. An advantage of this type of drive is that constant voltage is maintained under varying flying speeds. In brief, the torque component acting on the blade overcomes the torque of the generator.

A wind-driven generator for the 100 watt transmitter just described would have a high-voltage winding, marked H.V. in Figure 12, which would deliver 0.4 amperes (400 ma.) at 1000 volts d-c for plate and bias voltages and also a low-voltage

winding, marked L.V., which would supply 12 volts to the tube filaments. However, if a dynamotor were used the tube filaments would be connected to a 12 volt landing light battery which puts a drain on the battery of about 64 amperes, and the dynamotor would furnish the required plate potential. A retractable generator is one that can be swung into the fuselage when not in use.

"IGNITION SHIELDING" AND "BONDING" IN AIRPLANES. Many obstacles have had to be overcome in aircraft construction before it was possible to eliminate interference which prevented clear radio reception. The most noticeable disturbance comes from the ignition wires leading from the magneto to the spark plugs. This is due to the electromagnetic waves which are radiated by the conductors forming a circuit wherein an electrical spark occurs, such as magnetos, for example, which generate the high voltage for the spark plugs. To reduce this difficulty to a negligible amount the ignition cables are covered with a copper-wire braiding which is suitably grounded. In cases it requires shielding of spark plugs by means of special copper shields to reduce radiation by the plugs themselves.

All airplanes on which radio communication equipment is to be installed must be thoroughly bonded. The term bonding means that all metal parts of the airplane are connected by electrical conductors which are attached during the process of manufacture, this being done to eliminate the danger of sparks between metal parts.

AIRCRAFT ANTENNAS AND EQUIPMENT. Considerable experimentation is being conducted to find a type of antenna most suitable for aircraft radio transmission and reception. There are, in general, two types of antennas used; the fixed antenna and the trailing antenna. One type of fixed antenna, the vertical type, is shown in Figure 13 on a monoplane which carries mail. As the name implies, the trailing type floats under the plane while it is in flight and, therefore, it must be reeled out after taking-off and later reeled in before a landing is to be made. Note that a vertical antenna is sometimes called a pole antenna.

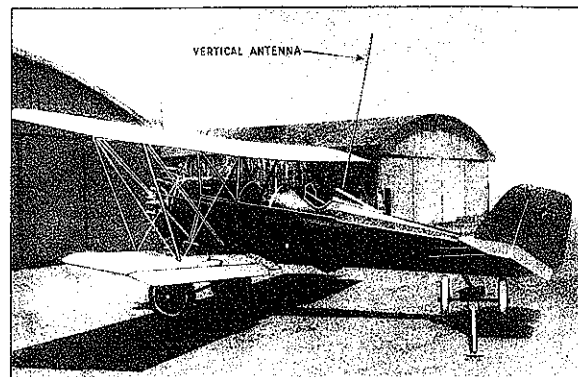
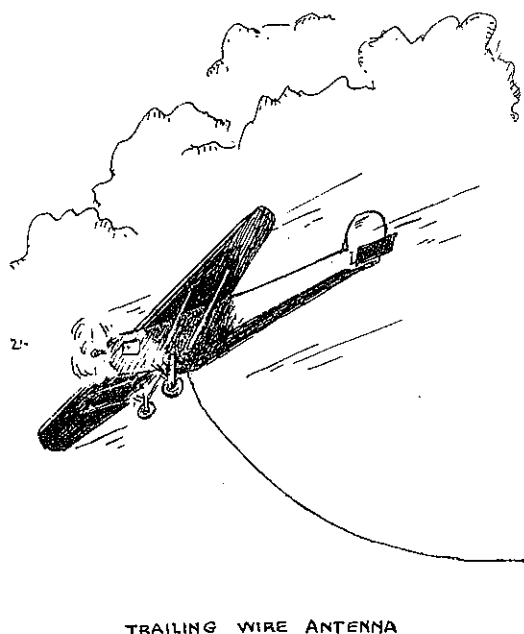
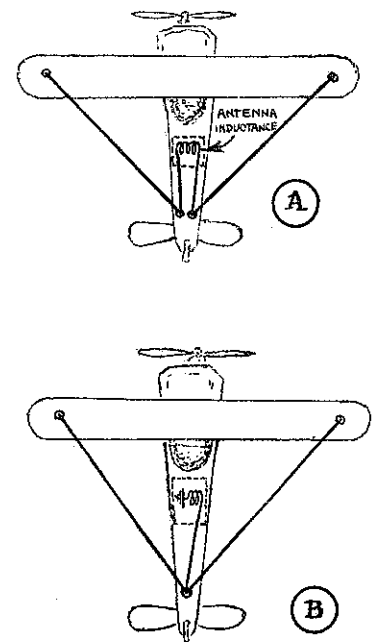


Figure 13



Under ordinary flying conditions and at the wavelengths used in aerial navigation, it has been found that a trailing wire of one or two hundred feet is a far better radiator of electromagnetic waves than a short fixed wire of perhaps only 6 to 50 ft. or more in length. The usual practice in antenna construction is to employ a fixed type for a one-man plane because here the pilot is also the operator and he cannot conveniently handle an antenna reel. In a one-man plane if only radio-reception is desired the vertical pole type usually answers the purpose but where two-way communication is to be carried on a greater range can be covered by using either of the horizontal fixed types shown in the sketches in Figure 13. The upper sketch A shows antenna conductors supported by insulators and stretched from the wing tips to the rear of the fuselage to form what is called a "doublet". The conductors join two other wires called transmission lines, which terminate at either end of the antenna inductance in the radio equipment. In the lower sketch B a slightly different form is used which may be classed with a "T" type antenna since the two conductors are connected at the rear and are spliced at this point with a wire which you would call a lead-in; the latter runs to one end of the antenna inductance and from the other end a connection is made to the ground as shown. It is to be remembered that the long trailing wire increases the transmission range over at least twice that of a fixed antenna.

A description of the antenna reel, the antenna wire, and the fairlead follows: The antenna wire which is usually of copper-clad steel and about 300 ft. long is carried on an insulated reel; the wire passes out through the fuselage by way of an insulating tube called a fairlead. A clamp holds the tubing in place where it passes through the floor of the plane. A small lever is provided at one side for locking the reel against rotation when sufficient wire is reeled out and a crank is used to reel in the wire before landing. A small weight attached to the remote end of the wire keeps the wire floating or trailing properly when the plane is in flight.

GROUNDING. The student invariably asks the question, "Where is the ground made on an airplane?" The answer to this is simple. A ground is made in the most convenient manner to some metal part of the plane such as a pipe, a strut, or crossbar; since all metal parts that enter the construction of a plane are "bonded", then, everything metal about the plane represents the ground. No specific recommendations can be given in this matter since conditions vary in different planes, but in general the ground is made by means of a braided copper wire attached to an approved ground clamp which is bolted to the metal part selected after having first thoroughly scraped and cleaned the surfaces to make a good electrical contact between the clamp and the metal part.

The advantages and disadvantages of the fixed antenna and the trailing antenna:

- Fixed Antenna:
- (1) Less flexible as to tuning.
 - (2) Takes up space in hangar. A pole antenna is about 6 ft. high.
 - (3) Possibility of fouling wires in event of breakage in flight.
 - (4) Less range for given power.
 - (5) For reception it has practically no directional tendencies.
- Trailing Antenna:
- (1) Less ignition interference in receiving.
 - (2) Transmitting range at least twice that of fixed antenna.
 - (3) Possibility of using the antenna itself as the tuning agency.

At this point it should be mentioned that in the case of the 100 watt transmitter previously described that when it is to be operated in the high wavelength band from 600 to 950 meters an antenna loading unit, like the one in Figure 9, is used so that the antenna can be resonated properly without requiring a very long trailing wire. It is estimated that about 225 ft. of wire is sufficient to cover this band. Of course, in the lower band, from 109 to 133 meters, this unit is not required.

RADIO RECEIVERS USED IN AVIATION.

As already explained in the early part of our lesson, practically every one-man plane engaged in scheduled flying is equipped with a radio receiver, called a beacon receiver, because it is used solely by the pilot to pick up directive radio range beacon signals, weather broadcasts, and other information transmitted by the Government airway stations. This kind of information is practically all that a pilot requires to enable him to fly a chosen course with the least delay and with greatest safety. With a beacon receiver in operation the pilot is always listening to either the radio range signals or the broadcast information since both are transmitted on the same frequency. In foggy weather when the visibility is poor and a pilot cannot see land-marks he is then forced to rely on beacon signals to fly along a course and arrive safely at his landing field. Herein lies radio's greatest usefulness to pilots in flight.

However, in addition to the beacon receivers, air-transport planes generally have a second receiver operated in conjunction with a transmitter for use in two-way communication between the pilot in flight and ground terminals. Although both types of receivers, a beacon and communication receiver, are operated on different frequency bands, yet the receivers have the same general features in that screen-grid tubes are employed and the sets are built extremely light in weight and are designed to stand up under extreme vibrations and severe shocks encountered during heavy landings. Also, their compact construction enables them to be installed in any available space in the plane. Only the remote control unit with headphones and tuning knob need be mounted within reach of the pilot. In the remainder of this lesson we will give diagrams and describe modern types of aircraft beacon and communication receivers.

AIRCRAFT BEACON RECEIVER. This receiver like all others contains everything necessary to convert the radio-frequency signals picked up by the antenna into audio-frequency signals. A glance at the schematic diagram of this receiver in Figure 14 shows that it consists of three stages of tuned radio-frequency amplification, or four tuned circuits, a detector, and two stages of audio-frequency amplification. Note that resistance coupling is used between the detector and the audio-frequency stages and that the plate rectification method of detection is used. The radio-frequency stages employ UX-222 screen-grid tubes and in the detector and first stage of audio-frequency amplification

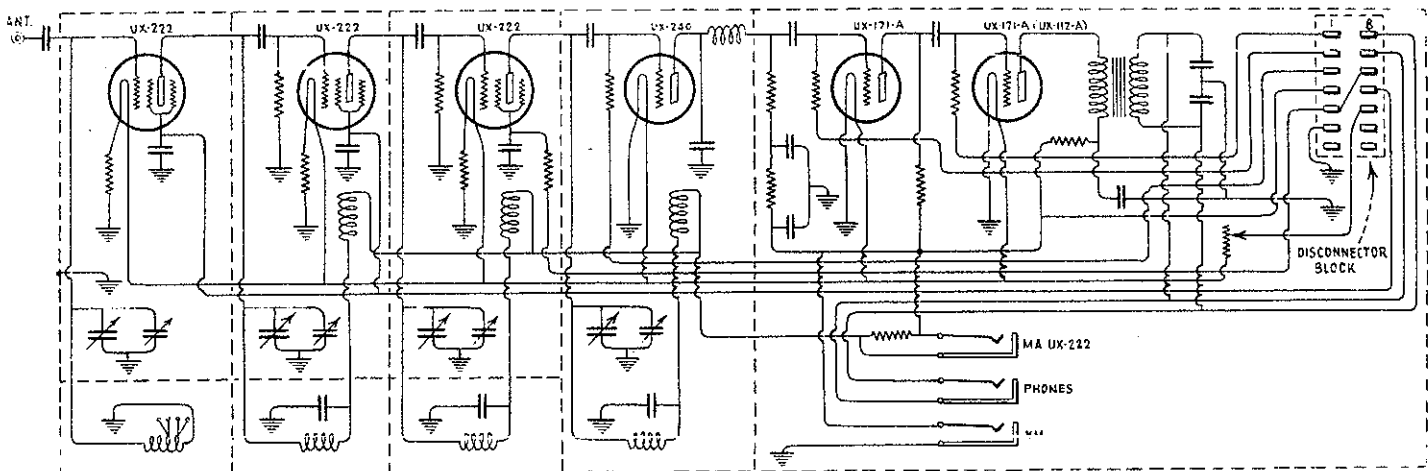


Figure 14

UX-240 tubes are used. Either a UX-112-A or a UX-171-A tube is used as the second stage audio or output tube. The circuit layout is arranged for modulated signals, no provision being made to receive signals from continuous wave transmitters. In the radio-frequency circuits use is made of tuned impedance coupling between the UX-222 tubes, an arrangement which makes possible four tuned circuits. A gang condenser is used for the four tuned circuits and is tuned by a single continuously variable tuning control. Due to the wonderful amplifying properties of the screen-grid tubes and design of the circuit the overall gain in voltage amplification will vary between one million and seven million. The volume control arrangement to adjust the overall gain is a potentiometer control of the screen-grid voltage, the potentiometer being located in the remote control unit.

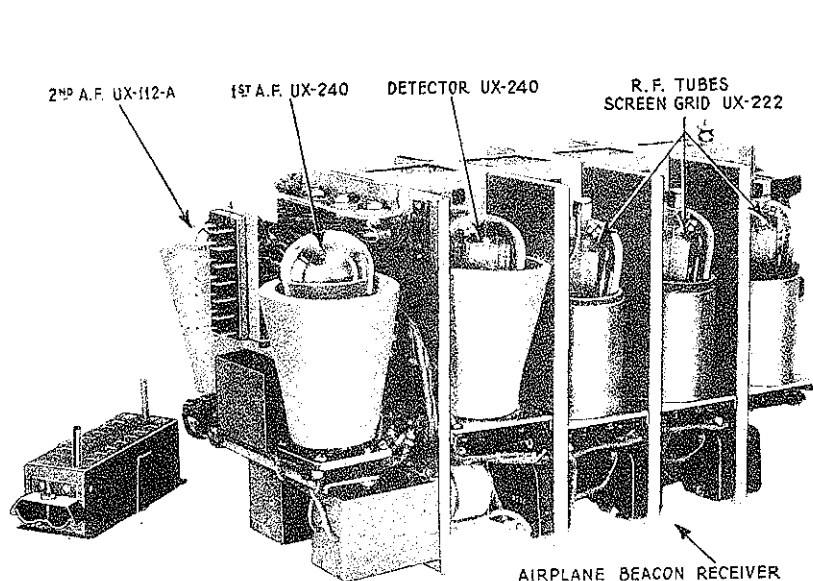


Figure 15

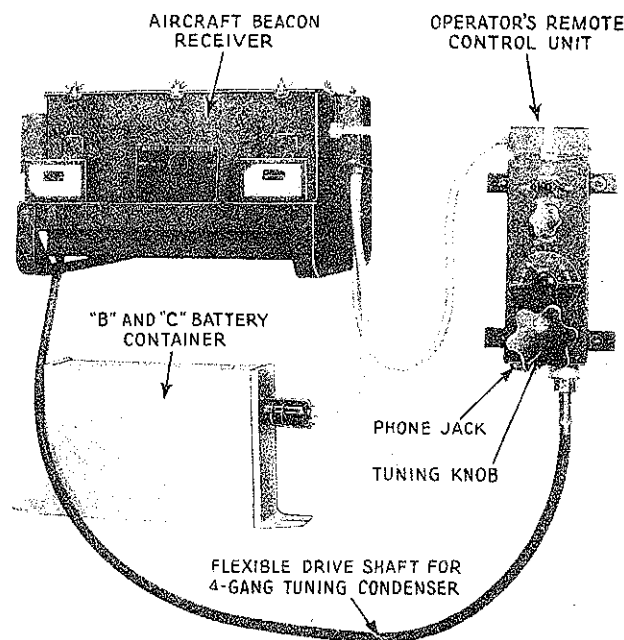


Figure 16

Now let us look at Figure 15. This shows the chassis of a beacon receiver as it appears after removal of the cover. Note how the different stages are placed in shielded compartments and also the connector block at the left which provides a convenient means for detaching the power leads from the receiver when servicing the set. In the four shielded compartments directly to the rear of the vacuum tubes are four variable tuning condensers; these cannot be seen in the photograph. The tubes are protected against vibration by spring sockets and "rubber foam" skirt vibration dampers.

The beacon receiver under discussion is model AR-1286 and is designed for operation with a pole antenna. The antenna consists of about 6 ft. of insulated wire which passes through a streamlined wooden mast or in some installations the antenna itself is an all-metal mast which is thoroughly insulated where it enters the fuselage; this type is usually erected in back of the pilot's cabin. The receiver parts are properly cushioned so that they will stand up under excessive vibration and shocks due to heavy landings. From the photograph in Figure 16 a good idea can be had regarding the special features involved to

provide remote control operation in present-day aircraft radio receivers. The receiver and battery supply unit can be located wherever space is available but the remote control box must be mounted within easy reach of the pilot or operator. A flexible steel shaft which runs through tubing and shielded conductor cables serves as the connecting links between these parts. The tubing is made long enough to reach from the set to the remote control box and high-gear ratio is used on the shaft to reduce the "twist" and "back lash" to a minimum which otherwise might cause difficulty when tuning. The electrical connections necessary between the receiver, the remote control box, and the battery box and landing light battery are made through shielded conductor cables with suitable plugs and jacks at each end for ease in attaching and detaching.

You will see in the photograph that the remote control box includes an "ON-OFF" switch, a volume control, a tuning control with calibrated dial and a headphone jack. The indicating dial is equipped with a set of adjustable stops so that the tuning may be limited to a given band, the two pointers being provided so that the operator may mark certain settings if he desires. It is interesting to mention that all of the important letters and figures on the panel are filled in with a luminous paint compound to allow the dial markings to be easily read during night flying.

This beacon receiver requires a filament or "A" battery supply of 6 volts, a plate or "B" supply of 45 and 135 volts, and a bias or "C" battery supply of 1.5, 3, and 9 or 27 volts depending on whether a UX-112-A or a UX-171-A tube is used in the output stage. Since it is customary to obtain the filament supply from the aircraft's landing light battery a series resistor of suitable value must be inserted in this circuit to drop the 12 volts delivered at the battery terminals to the required 5 volts. Provision is made so that a dynamotor-voltage divider combination may be utilized as the source of power for the plates of the tubes.

The schematic diagram shows only the circuits of the receiver up to the terminal strip; at this point the battery box cable and the cable from the remote control unit are attached to complete the electrical connections.

COMMUNICATION RECEIVER FOR AIRCRAFT. Since a receiver of this type is used for two-way communication with ground stations it is designed to work on the same antenna as the transmitter and is therefore arranged for reception of telephone, ICW and CW signals. Telephone is obviously the quickest and simplest form of communication, but code is also used on the larger planes which carry an operator or observer. Code is the only type of signal that will get through at times when great distances must be covered and in areas where static is unusually heavy. These adverse conditions are met especially along the international airways system. The diagram in Figure 17 is a schematic of the four-tube communication receiver known as model AR-1308 for use in airplanes. As the diagram indicates the circuit arrangement is simple and employs only one stage of radio-frequency amplification, a detector which operates on the principle of grid rectification since it is provided with a grid leak and condenser, and two stages of transformer coupled audio-frequency amplification.

An output transformer and jack are used into which the pilot's headphones are plugged. As the arrow in the diagram indicates inductive coupling is provided between the antenna and the first tuned circuit, the coupling being adjusted, however, at the time of installation and only for working on the high-frequency band, or from 3300 to 6700 kc. It can also be arranged for working in the

intermediate frequency band or from 240 to 500 kc. The schematic shows that a UX-222 is used in the radio frequency stage, two UX-201-A's used respectively in the detector which employs regeneration and in the first audio stage, and a UX-112-A in the second audio or output stage. However, provision is made to use either a UX-201-A or a UX-171-A in the output stage depending on the output signal voltage desired.

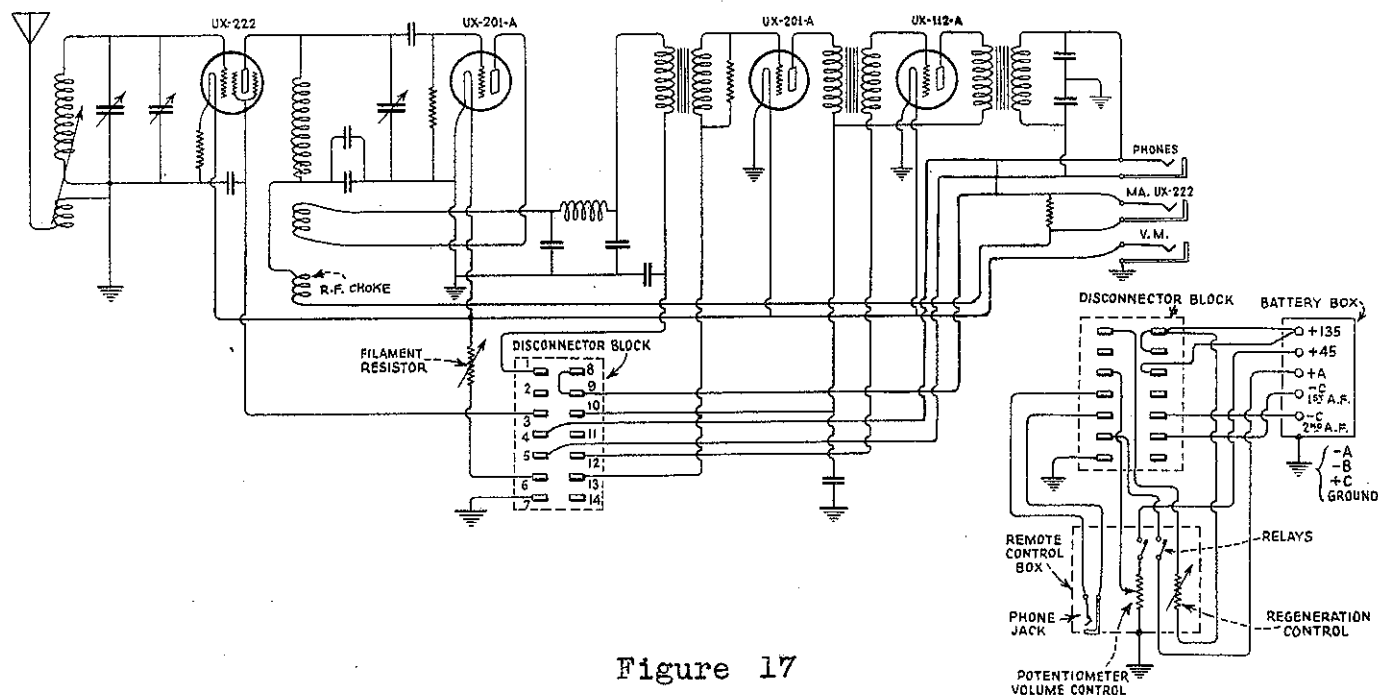


Figure 17

In regard to its outside physical appearance the communication receiver now under discussion and the beacon receiver pictured in Figure 17 are constructed somewhat alike inasmuch as both receivers are intended for remote control operation. According to latest developments in aircraft receivers, a combination 12 volt landing light battery and a charging generator is preferred for the "A" supply and in this case a resistance must be inserted in series with the source to lower the battery's 12 volts to the 5 volts required for the filament circuit.

SHORT-WAVE RADIO RECEIVER FOR GROUND STATIONS (12-80 METERS). Figure 18 is a diagram of a commercial high-frequency receiver of the latest type which may be used at airport terminals or at any other place for the reception of continuous wave telegraph signals or radio telephony within a frequency range of 3750 to 25,000 kc (12-80 meters) which is covered by three sets of plug-in coils. An additional set of coils may be used to cover 1,200 to 3,750 kc, or 80-150 meters. This is the circuit arrangement of a model AR-1496-D receiver

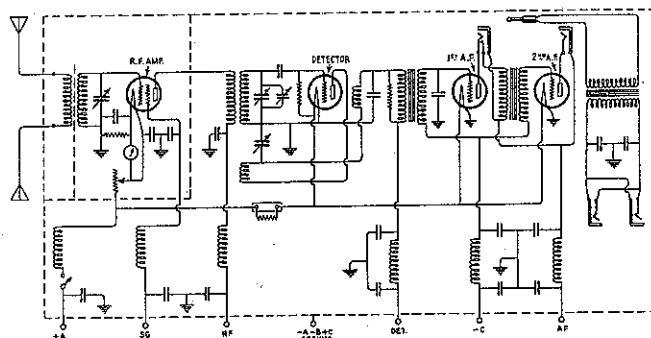


Figure 18

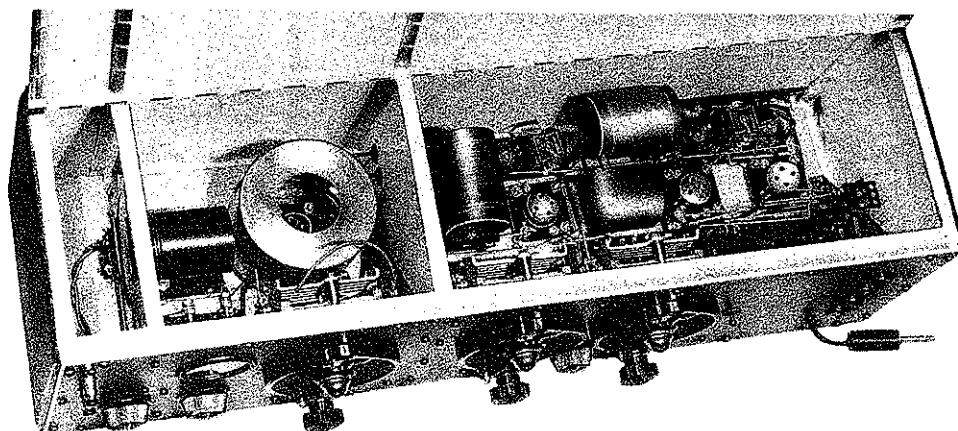


Figure 19

and as shown it consists of a tuned radio-frequency amplifier stage, a regenerative detector, and a two stage audio-frequency amplifier. A screen-grid four-element tube, UX-222 is used in the radio-frequency amplifier. Considerable radio-frequency gain is secured due to the high amplification factor of the UX-222 tube and, furthermore, the use of this tube eliminates the need for neutralization. The detector uses either a UX-240 or UX-841 tube and functions on the grid rectification principle with regeneration obtained by the use of a fixed tickler and controlled by a variable by-pass condenser. The detector regeneration circuit is so adjusted that oscillations start and stop smoothly at all frequencies within the range. The output of a two stage audio-frequency amplifier employing either two UX-201-A, or UX-210 tubes can be taken directly from the plate circuit or through an output transformer. Note that jacks are provided so that two sets of headphones can be used in parallel and, furthermore, they can be plugged into the output of the first audio or the second audio amplifier. Figure 19 shows (1) the input coupling coil, (2) the variable condenser, r-f grid coil, and by-pass condenser, and (3) the detector and audio stages mounted in three separate shielded compartments in the 12-80 meter set.

EXAMINATION - LESSON 59

1. (a) Who operates radio range beacon stations? (b) What is their purpose?
(c) What essential equipment is required in such a station?
2. How does radio aid air navigation?
3. What is meant by aural-type, and (b) visual-type of radiobeacon signal?
4. Describe a radio range antenna which provides directional radio beams.
5. Give the purpose of each essential circuit of a radio range transmitter.
6. Name and describe two types of antennas used for aircraft.
7. Suppose you were a pilot in a one-man plane and wished to follow a given airway, how would you make use of the aural type of radiobeacon as a guide?
8. What methods are employed to obtain power for an aircraft transmitter?
9. What special features are found in aircraft radio receivers?
10. (a) Explain what "bonding" means. (b) What means are employed to overcome electrical interference caused by airplane motors?